MYCORRHIZAE ASSOCIATED WITH AN INVASION OF *ERECHTITES GLOMERATA* (ASTERACEAE) ON SAN MIGUEL ISLAND, CALIFORNIA

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Abstract

Erechtites glomerata (Australian fireweed) is a perennial alien species that recently has invaded San Miguel Island, an island off the coast of southern California. It is presently advancing into a grassland dominated by *Distichlis spicata* and with scattered shrubs. As is typical of many weedy species, *E. glomerata* is facultatively mycotrophic on the island. Levels of colonization by vesicular-arbuscular mycorrhizal (VAM) fungi ranged from 0–30% of the root system. Nine species of VAM fungi were recovered from its root zone.

Australian fireweed, *Erechtites glomerata* (Poir.) DC. (Asteraceae), is a native of Australia and New Zealand that has been advancing slowly into the southern California region. It is a perennial that grows to 2 m in height. The common name "fireweed" comes from Australia and refers to the invasive nature of the plant in burn areas; however, it also can easily invade cleared or otherwise disturbed sites (Taylor 1964). On San Miguel Island, Santa Barbara Co., California, it has invaded and spread through a stable native grassland community (Fig. 1).

Vesicular-arbuscular mycorrhizae (VAM) are intimate, mutualistic associations formed between certain Zygomycetous fungi and plant roots. The fungi apparently are obligate symbionts, obtaining the bulk of their nutritional requirements from the "host" plant (Harley and Smith 1983). The fungi occupy the cortical cells of roots and produce hyphae that grow a few cm into the surrounding soil where they absorb phosphate that is beyond the root's depletion zone. Numerous studies (e.g., Nelsen and Safir 1982, Harley and Smith 1983, Fitter 1985) have shown that VAM ameliorate the effects of water stress and reduced availability of phosphorus in the soil. Growth improvements of up to 1100% have been achieved when plants growing in phosphorus-deficient soils were inoculated with VAM fungi (Mosse 1972).

VAM associations are extremely common, occurring in 95% of

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FIG. 1. *Erechtites glomerata* in a grassland community on San Miguel Island, California.

all plant families (Trappe in press). Although present in most soils, VAM fungi sometimes are absent from certain sites. The presence or absence of VAM fungi in soil can influence the ability of different plant species to establish in an area (Janos 1981, Miller 1979, Reeves et al. 1979). Plant species that require association with VAM fungi to complete their life cycle (=obligate mycotrophs) are unable to successfully invade and persist in sites that lack propagules of VAM fungi. Such VAM-free sites, therefore, are preferentially colonized by plant species that do not have an absolute requirement for VAM. These plant species are classified as non-mycotrophs or facultative mycotrophs, depending upon their ability to form VAM when the appropriate fungi are present. Because they grow well whether or not VAM fungi are present in the soil, facultative mycotrophs include many of the most troublesome weedy species (Trappe in press).

We examined plants of *E. glomerata* to determine their mycorrhizal status and to help explain their ability to be so invasive on San Miguel Island, a natural area managed by the National Park Service that functions under policy that calls for the removal of all such invasive, noxious weeds.

STUDY AREA

San Miguel is a 4000 ha island off the coast of southern California. It is the westernmost of the northern Channel Islands, occurring

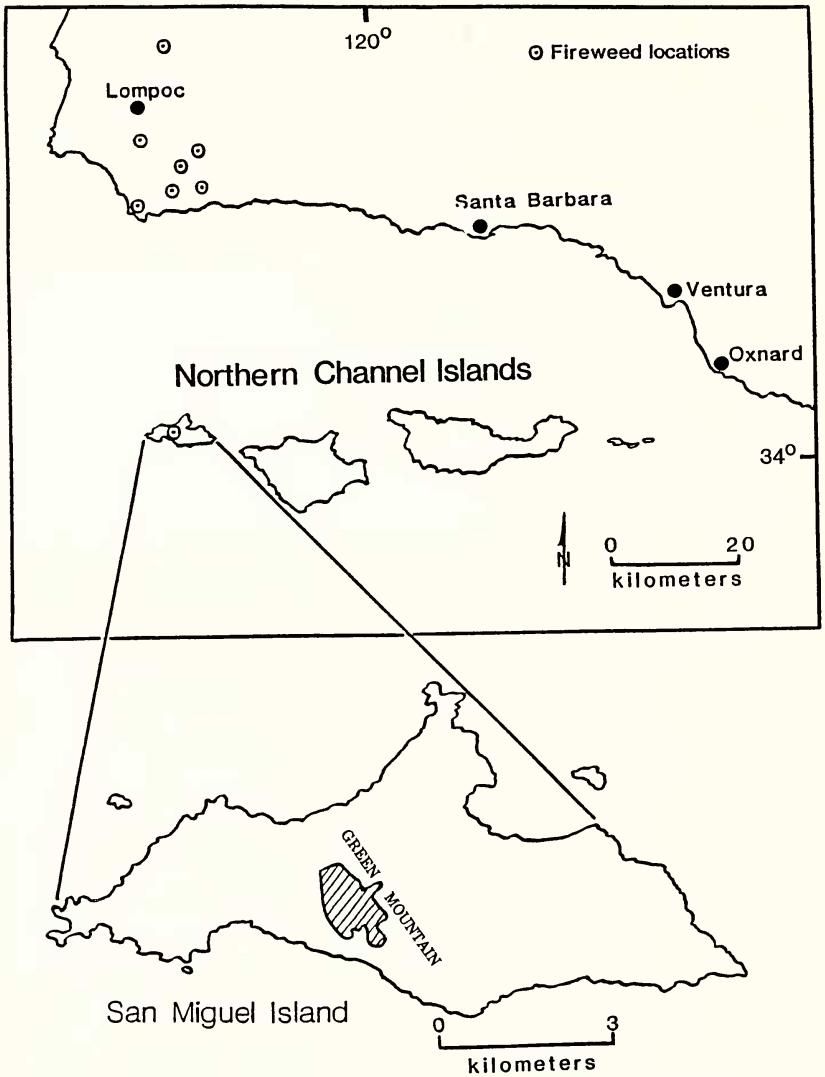


FIG. 2. Location of San Miguel Island in the southern California Bight area, showing the distribution (shaded area) of *Erechtites glomerata* (Australasian fireweed).

about 45 km south of Point Conception and 100 km west-southwest of Ventura (Fig. 2). Bedrock on the island is composed primarily of Cretaceous and early to mid-Tertiary conglomerates, sandstones, siltstones, shales, and volcanics. Structurally, the island represents the north flank of a folded and faulted anticline, whose axis trends northwest-southeast (Johnson 1979, Weaver et al. 1969). Much of

the island is covered with sand, both stabilized and unstabilized. In the area that is the subject of this report, the soils are of the vertisol type with a high level of expandable clay and shrink-swell characteristics (Johnson 1979).

The specific weather/climate characteristics of the island are relatively undefined due to a lack of adequate data. The island lies in the dry-summer, subtropical climate, commonly called Mediterranean (Trewartha 1954). Rainfall is in the range of 330–355 mm per year and the mean annual temperature is 13.7°C with an annual range of 3°C. The two most characteristic features of the weather are wind and fog. The wind is almost constant and comes principally out of the northwest. The winds commonly blow 30–40 km/hr with gusts up to 60 km/hr; strong northwest flows during the period of winter storms, bring winds of 70–80 km/hr. Morning fog is common throughout the year, but it is most constant during the summer months (Dunkle 1950, Weissman and Rentz 1977, NPS files).

The most important plant community on the island is grassland. There are two types: those dominated by introduced *Avena* (*A. fatua* L. and *A. barbata* Brot.) and *Bromus* (*B. mollis* L., *B. rubens* L. and *B. diandrus* Roth) and those dominated by the native *Distichlis spicata* (L.) Greene. Other community types include scrub dominated by *Haplopappus venetus* (HBK.) Blake, and coastal sage scrub, coastal bluff, coastal dunes, and a small coastal salt marsh (Hochberg et al. 1979).

Methods

The island was surveyed carefully in January 1985, and the total areal extent of the *Erechtites* population was mapped. One hundred quadrats (1 × 1 m) were placed randomly throughout the invasion area to assess the density of the population and to determine the species composition of the grassland community.

Root and soil samples were collected in July and November 1985, to determine the status of mycorrhizae. Roots of six specimens of *E. glomerata* were fixed in the field in formalin : acetic acid : ethanol : water (2:1:5:7, v/v/v/v). In the laboratory, roots were cleared and stained using a modification of the method of Phillips and Hayman (1970). The fixed roots were cleared by autoclaving for 3 minutes in 10% KOH. Cleared roots were rinsed in a dilute HCl solution, and mycorrhizae were stained by autoclaving the roots for 3 minutes in 0.05% trypan blue in lactic acid : glycerol : water (1:2:1, v/v/v). Roots were destained by autoclaving for 3 minutes in the above solution without trypan blue.

The extent of colonization of roots by VAM fungi was determined by estimating the percent (to nearest 10%) of the length of the absorbing root system that contained arbuscules, vesicles, hyphal coils, or internal hyphae of VAM fungi.

To determine the species of VAM fungi associated with the plants,

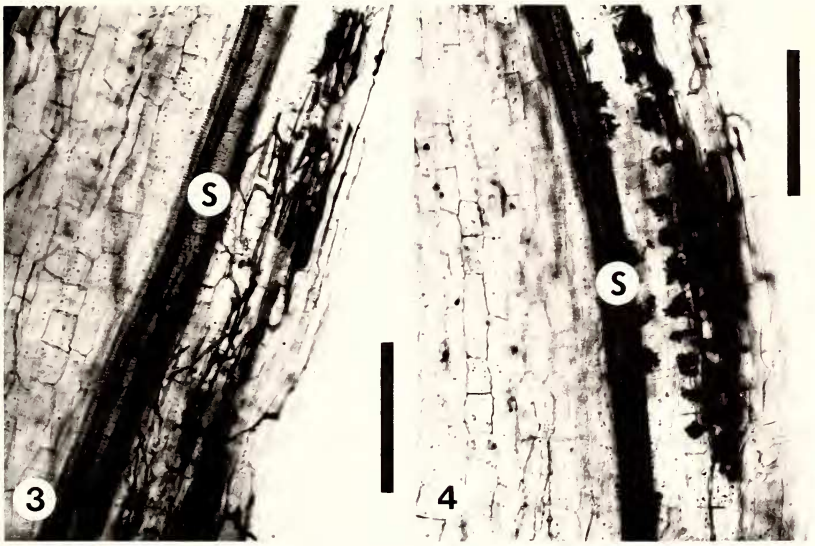
TABLE 1. COMPOSITION OF THE GRASSLAND COMMUNITY INTO WHICH *Erechtites glomerata* IS INVADING ON SAN MIGUEL ISLAND. Presence (%) was derived by dividing the number of plots in which a species was found by the total number of plots sampled. * = species that are considered alien to the San Miguel Island flora.

Species	Presence (%)
Distichlis spicata (L.) Greene	94
**Medicago polymorpha* L.	58
Amsinckia intermedia F. & M.	32
**Stellaria media* (L.) Vill.	18
Malacothrix incana (Nutt.) T. & G.	16
**Galium aparine* L.	14
**Sonchus oleraceus* L.	14
Calystegia macrostegia (Greene) Brummitt	10
Lupinus succulentus Dougl. ex Koch.	8
Dichelostemma pulchellum Heller	6
Eschscholzia californica Cham.	4
Atriplex californica Moq. in DC.	4
**Atriplex semibaccata* R. Br.	4
**Daucus pusillus* Michx.	4
Astragalus curtipes Gray	2
Chenopodium californicum (Wats.) Wats.	2
**Erodium moschatum* (L.) L'Her.	2

soil samples (ca. 500 cc) were collected from the root zones of two plants. A 75 cc subsample composed of 20–30 smaller subsamples withdrawn from the 500 cc sample was processed to recover spores. Spores were extracted from the soil by a water-sucrose centrifugation technique (Walker et al. 1982). Following centrifugation, spores were collected on a 5.5 cm filter paper (Whatman no. 1) in a Buchner funnel. The filter paper was examined at 30× with a dissecting microscope, and spores were removed, mounted in a polyvinyl alcohol mountant (Koske and Tessier 1983) and identified with the aid of a compound microscope at 400–1000×. Identifications were confirmed by comparison with type or authenticated specimens and by consultation with VAM taxonomists. Voucher specimens have been deposited in the mycological herbarium at the University of Rhode Island. Nomenclature of higher plants follows Munz (1968) except for *Erechtites glomerata,* which follows Barkley (1981). Nomenclature for fungi follows original authors that are given in Table 2.

RESULTS

The grassland that *Erechtites glomerata* is invading on San Miguel Island (Table 1) is dominated by *Distichlis spicata* with scattered patches of forbs, particularly *Amsinckia intermedia, Eschscholzia californica, Calystegia macrostegia, Chenopodium californicum, Sanicula arguta,* and *Dichelostemma pulchellum.* Scattered shrubs,



FIGS. 3, 4. VAM fungi in roots of *Erechtites glomerata.* Stele is indicated ("S"), scale bar is 50 μm. 3. Hyphae and hyphal coils. 4. Arbuscules and hyphae in cortical cells.

including *Baccharis pilularis* subsp. *consanguinea* and *Solanum douglasii,* also are present.

The flora of San Miguel Island was surveyed in 1978–79 (Hochberg et al. 1979), and no plants of Australasian fireweed were found. Plants of *E. glomerata* were first observed in May 1984, and the species was well established at that time (Junak pers. comm.). In January 1985, we determined that it covered an area of approximately 70 ha to the west of Green Mountain. Densities of stems within the population showed a pattern of spread from north to south in response to the prevailing winds. Density at the point of origin was 8800/ha. This decreased to 2100/ha and finally 500/ha with increasing distance southward.

TABLE 2. SPECIES OF VESICULAR-ARBUSCULAR MYCORRHIZAL (VAM) FUNGI ISOLATED FROM THE ROOT ZONE OF *Erechtites glomerata.*

Acaulospora laevis Gerd. & Trappe (Gerdemann and Trappe 1974)
Entrophospora infrequens Ames & Schneider (Ames and Schneider 1979)
Gigaspora calospora (Nicol. & Gerd.) Gerd. & Trappe (Gerdemann and Trappe 1974)
Glomus aggregatum Schenck & Smith (Schenck and Smith 1982)
Gl. intraradices Schenck & Smith (Schenck and Smith 1982)
Gl. pansihalos Berch & Koske (Berch and Koske 1986)
Gl. scintillans Rose & Trappe (Rose and Trappe 1980)
Gl. 598 (spores yellow-brown to red-brown, 70–140 μm diam., thick-walled)
Gl. 2163 (spores pale yellow, 60–120 μm diam., thin-walled)

Five of the six plants of Australasian fireweed sampled possessed vesicular-arbuscular mycorrhizae (Figs. 3, 4), with levels of VAM colonization ranging up to 30% ($\bar{x}$ = 14%). Nine species of VAM fungi were isolated from the root zone of *E. glomerata* (Table 2). Species that produced the most numerous spores in association with this host were *Glomus pansihalos* and *Gigaspora calospora.* Two of the species, *Glomus* 598 and *Gl.* 2163, could not be assigned to existing taxa and apparently are undescribed new species.

Discussion

Erechtites glomerata is an aggressive alien that newly inhabits San Miguel Island. Introduction apparently resulted from seeds being carried across the Santa Barbara Channel from the mainland (Fig. 2). At this time, it is found nowhere else on the Channel Islands. Although in its native Australia it is most common in burned or disturbed areas, on San Miguel Island this fireweed is invading an established native grassland. Its spread has been rapid and effective with fireweed becoming a major component of the grassland community.

We have found eight of the nine species of VAM fungi recovered in the present study occurring in association with native plant species on San Miguel Island, a typical situation because VAM fungi usually have wide host ranges (Harley and Smith 1983). *Glomus scintillans,* the one species that has not been found thus far in the root zones of other plants on the island, was described originally from a shrub desert site in eastern Oregon (Rose and Trappe 1980), where it was associated with shrubs that harbor nitrogen-fixing actinomycetes in their roots.

Of the six other species that have been described previously, four have been found in the southwestern U.S.: *Entrophospora infrequens* in mainland Ventura Co., California (Ames and Schneider 1979, Nemec et al. 1981); *Acaulospora laevis, Entrophospora infrequens, Gigaspora calospora,* and *Glomus intraradices* from the Sonoran Desert in Arizona (Bloss 1986); and *Glomus intraradices* from Anza Borrego State Park in southern California (Bethlenfalvay et al. 1984). The other two species (*Glomus aggregatum* and *Glomus pansihalos*) have been found in the Great Lakes Region and on the east coast of the United States (Koske 1987, Koske and Tews in press, P. Olexia, pers. comm.).

Erechtites glomerata appears to be a facultative mycotroph that fits within the pattern of tropical weedy species in which those plants that produced light seeds were shown to be the least dependent upon mycorrhizae (Janos 1980). This characteristic explains in part why *E. glomerata* is such a successful invader, and should be considered in any management strategy that the National Park Service might develop for its control or removal.

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NOTEWORTHY COLLECTIONS

British Columbia

Salix tweedyi (Bebb) C. R. Ball (Salicaceae).—Bolean Lake, northeast of Falkland. 50°32′N, 119°30′W, 1440 m, in a *Salix, Carex* swamp at s. end of lake in front of resort, associated with *S. barclayi,* 25 Jul 1986, *T. C. Brayshaw 86-23, -24, -26, -27, -28, -29, -30* (CAN, V).

Previous knowledge. This species was first collected in Canada at this locality in 1941 by C. L. Hitchcock and J. S. Martin. Their collection number *7524* was distributed as *S. barclayi* Anderss. In 1962, A. Cronquist recognized that a duplicate at NY was actually *S. tweedyi.*This specimen evidently was the basis for the inclusion of BC in the distribution of the species in Hitchcock et al. (*Vascular Plants of the Pacific Northwest* 2:69, 1964). Specimens of *7524* in RM and WTU also are *S. tweedyi,* but the specimen in A was correctly named *S. barclayi.*

Significance. These collections confirm the occurrence of *S. tweedyi* in Canada at a locality about 200 km n. of its nearest locality in Washington (Okanogan Co., Tiffany Mt.). This species is rare in BC.—George W. Argus, National Herbarium, Museum of Natural Sciences, Ottawa, ON K1A 0M8 and T. C. Brayshaw, British Columbia Provincial Museum, Victoria, BC V8V 1X4, Canada.

New Mexico

Salix geyeriana Anderss. (Salicaceae).—Catron Co., Mogollon Mountains, Gilita Cr. at confluence of Indian Cr., ca. 31 km e. of Mogollon, 33°24′N, 108°34′W, 8000